ANALOG DEVICES

AN-396 APPLICATION NOTE

ONE TECHNOLOGY WAY • P.O. BOX 9106 • NORWOOD, MASSACHUSETTS 02062-9106 • 617/329-4700

Understanding Accelerometer Scale Factor and Offset Adjustments

by Charles Kitchin

INTRODUCTION

The ADXL50 and ADXL05 accelerometers are small, low cost, easy to use devices. These modern integrated circuits have an onboard buffer amplifier that allows the user to change the output scale factor and 0 *g* bias level.

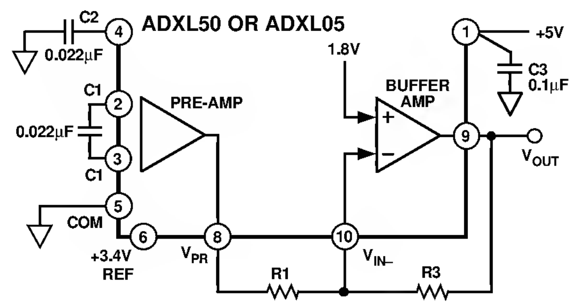
The output scale factor of an accelerometer is simply how many volts output are provided per *g* of applied acceleration. This should not be confused with its resolution. The resolution of the device is the lowest *g* level the accelerometer is capable of measuring. Resolution is principally determined by the device noise and the measurement bandwidth.

The 0 *g* bias level is simply the dc output level of the accelerometer when it is not in motion or being acted upon by the earth's gravity.

SETTING THE ACCELEROMETER'S SCALE FACTOR

Figure 1 shows the basic connections for using the onboard buffer amplifier to increase the output scale factor. The nominal output level in volts from V_{PR} (the preamplifier output) is equal to the *g* forces applied to the sensor (along its sensitive axis) times the output scale factor of the accelerometer. The ADXL50 has a preset scale factor of 19 mV/*g* at its preamplifier output, V_{PR}; the ADXL05's scale factor is 200 mV/*g*. The use of the buffer is always recommended, even if the preset scale factor is adequate, as the buffer helps prevent any following circuitry from loading-down the V_{PR} output.

In Figure 1, the output scale factor is simply the output at V_{PR} times the gain of the buffer, which is simply the value of resistor R3 divided by R1. In all cases, never use more gain than is needed to provide a convenient scale factor, as the buffer gain not only amplifies the signal but any noise or drift as well. Too much gain can also cause the buffer to saturate and clip the output waveform.

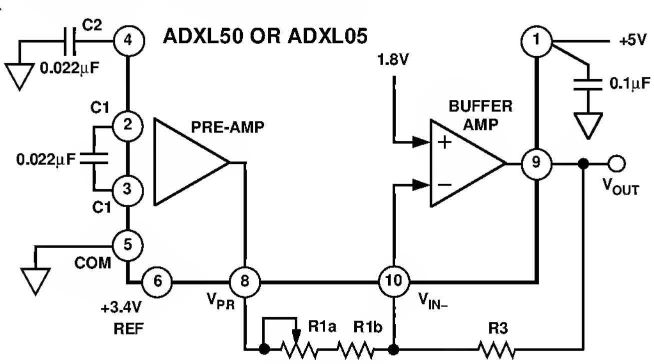


OUTPUT SCALE FACTOR = $\frac{R3}{R1}$ x V_{PR} OUTPUT

V_{PR} OUTPUT: ADXL50: 19mV/*g*, ADXL05: 200mV/*g*

Figure 1. Basic Buffer Connections

The circuit of Figure 1 is entirely adequate for many applications, but its accuracy is dependent on the pretrimmed accuracy of the accelerometer, and this will vary by product type and grade. For the highest possible accuracy, an external trim is recommended. As shown by Figure 2, this consists of a potentiometer, R1a, in series with a fixed resistor, R1b.



OUTPUT SCALE FACTOR = $\frac{R3}{(R1a + R1b)}$ x V_{PR} OUTPUT

V_{PR} OUTPUT: ADXL50: 19mV/*g*, ADXL05: 200mV/*g*

Figure 2. External Scale Factor Trimming

SETTING THE ACCELEROMETER'S 0 *g* BIAS LEVEL, AC COUPLED RESPONSE

If a dc (gravity sensing) response is not needed, then the use of ac coupling between V_{PR} and the buffer input is highly recommended. AC coupling virtually eliminates any 0 *g* drift and allows the maximum buffer gain without clipping. The basic ac coupling circuit is shown in Figure 3. Resistor R1 and Capacitor C4 together form a high pass filter whose corner frequency is 1/(2 π R1 C4). This means that this simple filter will reduce the signal from V_{PR} by 3 dB at the corner frequency and it will continue to reduce it at a rate of 6 dB/octave (20 dB per decade) for signals below the corner frequency.

The 0 *g* offset level of the ADXL50 and ADXL05 accelerometers is preset at +1.8 V. There are two simple ways to change this to a more convenient level, such as +2.5 V which, being at the middle of the supply voltage, provides the greatest output voltage swing.

When using the ac coupled circuit of Figure 3, only a single resistor, R2, is required to swing the buffer output to +2.5 V. Since the "+" input of the buffer is referenced at +1.8 V, its summing junction, Pin 10, is also held constant at +1.8 V. Therefore, to swing the buffer's output to the desired +2.5 volt 0 *g* bias level, its output must move up +0.7 V (2.5 V–1.8 V = 0.7 V). Therefore, the current needed to flow through R3 to cause this change, I_{R3}, is equal to:

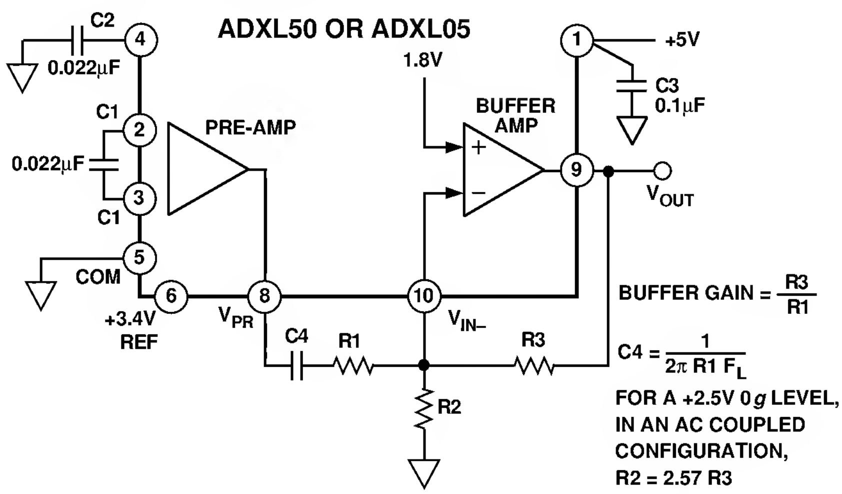
$$I_{R3} = \frac{0.7\ Volts}{R3\ in\ Ohms}$$

In order to force this current through R3, the same current needs to flow from Pin 10 to ground through resistor R2. Since Pin 10 is always held at +1.8 V, R2 is equal to:

$$R2 = \frac{1.8\ Volts}{I_{R3}}$$

Therefore, for an ac coupled connection and a +2.5 V 0 *g* output:

$$R2 = \frac{1.8\ Volts \times R3}{0.7\ Volts} = 2.57 \times R3$$



ADXL05 RECOMMENDED COMPONENT VALUES

FULL-SCALE RANGE	SCALE FACTOR IN mV/*g*	DESIRED LOW FREQUENCY LIMIT, F_L	R1 IN kΩ	CLOSEST C4 VALUE	R3 IN kΩ	R2 VALUE IN kΩ FOR +2.5V 0*g* LEVEL
±2*g*	1000	30Hz	49.9	0.10µF	249	640
±5*g*	400	30Hz	127	0.039µF	249	640
±2*g*	1000	3Hz	49.9	1.0µF	249	640
±5*g*	400	1Hz	127	1.5µF	249	640
±5*g*	400	0.1Hz	127	15µF	249	640

ADXL50 RECOMMENDED COMPONENT VALUES

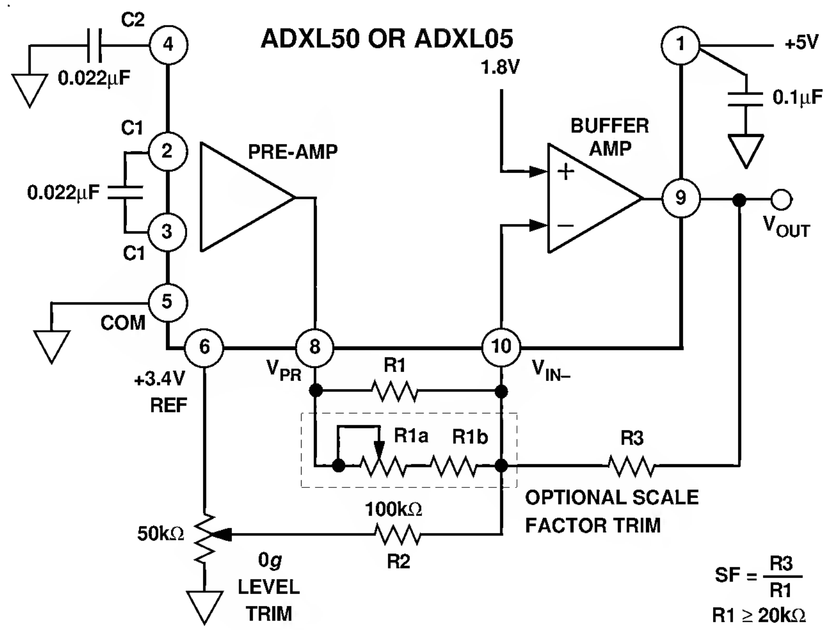
FULL-SCALE RANGE	SCALE FACTOR IN mV/*g*	DESIRED LOW FREQUENCY LIMIT, F_L	R1 IN kΩ	CLOSEST C4 VALUE	R3 IN kΩ	R2 VALUE IN kΩ FOR +2.5V 0*g* LEVEL
±10*g*	200	30Hz	24	0.22µF	249	640
±20*g*	100	10Hz	24	0.68µF	127	326
±10*g*	200	3Hz	24	2.2µF	249	640
±20*g*	100	1Hz	24	6.8µF	127	326
±10*g*	200	0.1Hz	24	68µF	249	640

Figure 3. Typical Component Values for AC Coupled Circuit

SETTING THE ACCELEROMETER'S 0 *g* BIAS LEVEL, DC COUPLED RESPONSE

When a true dc (gravity) response is needed, the output from the preamplifier, V_{PR}, must be dc coupled to the buffer input.

With a dc coupled connection, any difference between a nonideal +1.8 V 0 *g* level at V_{PR} and the fixed +1.8 V level at the buffer's summing junction will be amplified by the gain of the buffer. If the 0 *g* level only needs to be approximate and the buffer is operated a low gain, a single fixed resistor, R2, can still be used. But to obtain the exact 0 *g* output desired or to allow the maximum output voltage swing from the buffer, the 0 *g* offset will need to be externally trimmed using the circuit of Figure 4. Normally, a value of 100 kΩ is typical for R2.



ADXL05 0*g* TRIM ONLY, RECOMMENDED COMPONENT VALUES FOR VARIOUS OUTPUT SCALE FACTORS

FULL SCALE	mV PER *g*	R1 kΩ	R3 kΩ
±1*g*	2000	30.1	301
±2*g*	1000	40.2	200
±4*g*	500	40.2	100ßœ
±5*g*	400	49.9	100

ADXL05 WITH 0*g* AND SF TRIMS

FULL SCALE	mV PER *g*	R1a kΩ	R1b kΩ	R3 kΩ
±1*g*	2000	10	24.9	301
±2*g*	1000	10	35.7	200
±4*g*	500	10	35.7	100
±5*g*	400	10	45.3	100

ADXL50 0*g* TRIM ONLY, RECOMMENDED COMPONENT VALUES FOR VARIOUS OUTPUT SCALE FACTORS

FULL SCALE	mV PER *g*	R1 kΩ	R3 kΩ
±10*g*	200	23.7	249
±20*g*	100	26.1	137
±40*g*	50	39.2	105
±50*g*	40	49.9	105

ADXL50 WITH 0*g* AND SF TRIMS

FULL SCALE	mV PER *g*	R1a kΩ	R1b kΩ	R3 kΩ
±10*g*	200	5	21.5	249
±20*g*	100	5	23.7	137
±40*g*	50	10	34.0	105
±50*g*	40	10	45.3	105

Figure 4. Typical Component Values for Circuit with External 0 g or 0 g and Scale Factor Timing

Increasing its resistance above this value makes trimming the offset easier, but may not provide enough trim range to set V_{OUT} equal to +2.5 V for all devices.

The buffer's maximum output swing should be limited to ±2 volts, which provides a safety margin of ±0.25 volts before clipping. With a +2.5 volt 0 *g* level, the maximum gain the buffer should be set to (R3/R1) equals:

$$\frac{2\ \text{Volts}}{\text{Output Scale Factor at } V_{PR} \text{ Times the Max Applied Acceleration in } g\text{s}}$$

Note that the value of R1 should be kept as large as possible, 20 kΩ or greater, to avoid loading down the V_{PR} output.

The device scale factor and 0 *g* offset levels can be calibrated using the earth's gravity as explained in the ADXL50 and ADXL05 data sheets.

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